I CLAIM:

1. Endothermic catalytic reaction apparatus comprising:

a) a U-shaped flow through tubular reaction chamber disposed upright within a combustion chamber, and a catalyst contained within said reaction chamber for the conversion of hydrocarbon to industrial gases by reaction with steam; said reaction chamber having an upper portion, and there being a convection chamber extending about said upper portion to enhance the transfer of heat from combustion products in the reaction chamber, and

b) a radiant burner generally vertically disposed within the combustion chamber and having a gas permeable zone that promotes the flameless combustion of fuel and oxidant supplied to said burner in order to heat a metal fiber surface of the burner to incandescence for radiating heat to the reaction chamber; said radiant burner configured so that the angle of radiation is predominantly incident upon the surface of the tubular reaction chamber.

2. The combination of claim 1 wherein said tubular reaction chamber comprises a tube having outer diameter or diameters ranging from about ¾ inch to about 4 inches along the tube length.

3. The combination of claim 1 wherein said tubular reaction chamber is sized for creation of mass velocities ranging from 400 $lb/ft^2/h$ to 1500 $lb/ft^2/h$.

4. The combination of claim 1 wherein said catalyst in the tubular reaction chamber has average catalyst particle diameters ranging from 1/8 to 1 inch for producing gas pressure drops ranging from 1 psi to 8 psi during flow through the reaction chamber.

5. The combination of claim 1 wherein said tubular reaction chamber has a gas exit end temperature ranging from 1150°F to 1400°F when heated by said radiant burner, in operation.

6. The combination of claim 1 wherein said tubular reaction chamber has legs and an arc-shaped bend connecting said legs, and said legs and bend have maximum tube wall temperatures ranging from 1300°F to 1600°F when heated by said radiant burner, in operation.

7. The combination of claim 1 wherein said tubular reaction has average heat fluxes ranging from 3,000 btu/ft^2/h to 10,000 btu/ft^2/h, when heated by said radiant burner in operation.

8. The combination of claim 1 wherein said tubular reaction chamber is sized to have capacity to generate hydrogen plus carbon monoxide product in volumetric quantities ranging from 50 SCFH to between 500 and 1500 SCFH.

9. The combination of claim 1 wherein said radiant burner comprises a supported porous ceramic material having extended life at operating temperatures up to 2100°F.

10. The combination of claim 1 wherein said radiant burner comprises a supported metal fiber material consisting essentially of an alloy containing principally iron, chromium, and aluminum and smaller quantities of yttrium, silicon, and manganese, said alloy having extended life at operating temperatures up to 2000°F.

11. The combination of claim 1 wherein said radiant burner is configured to direct radiation at an included angle of radiation between 45-180 degrees.

12. The combination of claim 1 wherein said radiant burner has a hemispherical shape.

13. The combination of claim 1 wherein said radiant burner has surface temperatures ranging from 1500°F to 1900°F, in operation.

14. The combination of claim 1 wherein said radiant burner has an operating combustion intensity typically ranging from 150,000 btu/ft^2/h to 350,000 btu/ft^2/h, wherein the combustion intensity is defined as the higher heating value of the fuel combusted divided by the permeable radiant burner surface area.

15. The combination of claim 1 wherein said radiant burner has an operating excess air ratio typically ranging from 30% to 100%, wherein the excess air ratio is defined as percent combustion air in excess of the stoichiometric amount required for complete combustion of the burner fuel.

16. Endothermic catalytic reaction apparatus, comprising

a) a combustion chamber,

b) a tubular reaction chamber having two generally tubular legs extending in generally parallel, spaced apart relation within the combustion chamber,

c) catalyst within said reaction chamber for reacting with a hydrocarbon and steam received within the reactor chamber, to produce hydrogen and carbon dioxide,

d) a generally tubular radiant burner within the combustion chamber and extending in generally parallel relation to at least one of said legs, said burner spaced from said legs,

e) said two legs having axes, and said tubular burner having an axis which is spaced in offset relation to a plane defined by said leg axes.

17. The combination of claim 16 wherein said burner axis is approximately equidistant from said leg axes.

18. The combination of claim 16 wherein said burner has heat radiating surfaces configured to radiate heat predominately in directions toward said legs.

19. The combination of claim 16 wherein said legs are in series communication.

20. The combination of claim 16 wherein the burner has a gas permeable metal fiber zone γ_1, and non-gas permeable zone γ_2, where γ_1 faces said legs and γ_2 faces away from said legs, γ_1 subtending an angle that is less than 180°.

21. Endothermic catalytic reaction apparatus comprising:

a) a helical tubular flow through reaction chamber disposed within a combustion chamber, and catalyst contained within said reaction chamber for the conversion of hydrocarbon to industrial gases by reaction with steam; said helical tubular reaction chamber having an upper portion, and there being a convection chamber extending about said upper portion to enhance the transfer of heat from combustion products in the reaction chamber and an exit section to convey reaction products to the exit means, and

b) a radiant burner vertically disposed within said combustion chamber and having a gas permeable zone that promotes the flameless combustion of fuel and oxidant supplied to said burner in order to heat the metal fiber surface of the burner to incandescence for radiating heat energy to the reaction chamber; said radiant burner configured to radiate uniformly in radial directions.

22. The combination of claim 21 wherein said tubular reaction chamber comprises a tube having outer diameters ranging from about ¾ inch to about 4 inches, along the tube length.

23. The combination of claim 21 wherein said tubular reaction chamber defines a coil having an outer coil diameter ranging from 6 to 36 inches.

24. The combination of claim 21 wherein said helical tubular reaction chamber is for creation of mass velocities ranging from
400 $lb/ft^2/h$ to 1500 $lb/ft^2/h$.

25. The combination of claim 21 wherein said catalyst in the helical tubular reaction chamber has average catalyst particle diameters ranging from ¼ to 1 inch for producing gas pressure drops ranging from 1 psi to 8 psi during flow through the reaction chamber.

26. The combination of claim 21 wherein said helical tubular reaction chamber has gas exit end temperature ranging from 1150°F to 1400°F, when heated by said radiant burner, in operation.

27. The combination of claim 21 wherein said helical tubular reaction chamber has maximum tube wall temperatures ranging from 1300°F to 1600°F, when heated by said radiant burner, in operation.

28. The combination of claim 21 wherein said helical tubular reaction chamber has average heat fluxes ranging from 3,000 $btu/ft^2/h$ to 10,000 $btu/ft^2/h$, when heated by said radiant burner in operation.

29. The combination of claim 21 wherein said helical tubular reaction chamber is sized to have capacity to generate hydrogen plus carbon monoxide product in volumetric quantities ranging from 50 SCFH to between 100 and 1500 SCFH.

30. The combination of claim 21 wherein said radiant burner comprises a supported porous ceramic material having extended life at operating temperatures up to 2100°F.

31. The combination of claim 21 wherein said radiant burner comprises a supported metal fiber material consisting essentially of an alloy containing principally iron, chromium, and aluminum and smaller quantities of yttrium, silicon, and manganese, said alloy having extended life at operating temperatures up to 2000°F.

32. The combination of claim 21 wherein said radiant burner is configured to radiate heat energy in a substantially uniform radial pattern.

33. The combination of claim 21 wherein said radiant burner has surface temperatures ranging between 1500°F and 1900°F, in operation.

34. The combination of claim 21 wherein said radiant burner has an operating combustion intensity typically ranging from 150,000 btu/ft^2/h to 350,000 btu/ft^2/hr, wherein the combustion intensity is defined as the higher heating value of the fuel combusted divided by the permeable radiant burner surface area.

35. The combination of claim 21 wherein said radiant burner has an operating excess air ratio typically ranging from 30% to 100%, wherein the excess air ratio is defined as percent combustion air in excess of the stoichiometric amount required for complete combustion of the burner fuel.

36. The combination of claim 22 wherein the coil has free area in the range 50% to 75%, wherein the free area is defined as the ratio of the free area between successive coil turns and the cylinder that bisects the helical coil circle.

37. The combination of claim 21 wherein the convection chamber has an inlet within the combustion chamber, and an outlet outside the combustion chamber.

38. The combination of claim 1 including a fuel cell in operating communication with said reaction chamber, to receive hydrogen therefrom.

39. The combination of claim 21 including a fuel cell in operating communication with said reaction chamber, to receive hydrogen therefrom.

40. The method of converting a hydrocarbon to industrial gases, that includes:

a) providing a U-shaped flow through tubular reaction chamber disposed upright within a combustion chamber, and a catalyst contained within said reaction chamber for the conversion of said hydrocarbon to said industrial gases by reaction with steam; said reaction chamber having an upper portion, and there being a convection chamber extending about said upper portion to enhance the transfer of heat from combustion products in the reaction chamber,

b) providing a radiant burner generally vertically disposed within the combustion chamber and having a gas permeable zone that promotes the flameless combustion of fuel and oxidant supplied to said burner in order to heat a fiber surface of the burner to incandescence for radiating heat to the reaction chamber; said radiant burner configured so that the angle of radiation is predominantly incident upon the surface of the tubular reaction chamber,

c) supplying said hydrocarbon and steam to the reaction chamber heated by said radiant burner,

d) and removing said industrial gases including hydrogen from the reaction chamber.

41. The method of claim 40 including providing a gas conditioning system and fuel cell, and supplying said hydrogen to said fuel cell.

42. The method of claim 40 wherein said fiber surface of the burner consists of at least one of the following:

a) ceramic

b) metal.

43. Endothermic catalytic reaction apparatus that includes a combustion chamber, comprising:

a) a straight tubular outer conduit concentrically disposed around an inner conduit to form a reaction chamber containing catalyst in the annular space between the outer conduit wall and the inner conduit wall, for conversion of hydrocarbon to industrial gases by reaction with steam, and an inner conduit defined space for the return flow of reactant gases to an exit means; said tubular reaction chamber having one end that extends into the combustion chamber and an opposite end that extends outside of the combustion chamber, and there being inlet means that is in communication with the annular space and an exit means that is in communication with the inner conduit defined space,

b) and a radiant burner vertically disposed within said combustion chamber and having a gas permeable zone that promotes the flameless combustion of fuel and oxidant supplied to said burner in order to heat the metal fiber surface of the burner to incandescence for radiating heat energy to the reaction chamber.

44. The combination of claim 43 wherein a multiplicity of said tubular reaction chambers are provided and are concentrically disposed around a centrally located and vertically disposed cylindrical radiant burner having a 360 degree radiant arc.

45. The combination of claim 43 wherein there is a convection chamber extending about a portion of the tubular reaction chamber in the proximity of the end containing the reactant gas inlet and outlet means to enhance heat transfer from combustion products; said convection chamber having an inlet means that is in communication with the combustion chamber and an exit means for combustion products that is outside the combustion chamber.

46. The combination of claim 43 wherein the reactant gases flowing inside the inner conduit transfer heat to the reaction chamber.

47. The combination of claim 43 wherein said radiant burner is comprised of a supported metal fiber material.

48. The combination of claim 43 wherein said radiant burner is comprised of a supported ceramic fiber material.